CLAIMS

What is claimed is:

1. A method of generating weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a plurality of receivers, and wherein the transmitter includes a plurality of antennae, the method comprising:
   a) initializing a parameter set and a weight vector set;
   b) updating the weight vector set based on an inverse cost function;
   c) updating the parameter set; and
   d) returning to the act (b).

2. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein updating the weight vector act (b) is based upon feedback from the receiver.

3. The method of generating weighted transmit signals with nulling as defined in Claim 2, wherein the communication system adjusts a transmission signal according to the parameter set to enable a receiver feedback.

4. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the communication system comprises a DS-CDMA communication system.

5. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the inverse cost function is represented by the following equation:

$$\text{general inverse cost function} = \frac{\text{delivered power to a desired receiver}}{\text{interference power to all proximate receivers}}.$$

6. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the inverse cost function is represented by the following equation:

$$J = \frac{\left|\mathbf{w}_m{}^{\mathrm{H}}(i)\mathbf{c}_m(i)\right|^2}{\sum_{k=0}^{K-1} A_k \left|\mathbf{w}_m{}^{\mathrm{H}}(i)\frac{\mathbf{c}_k(i)}{\left\|\mathbf{c}_k(i)\right\|}\right|^2 + B}$$; where J = inverse cost function.

7. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the weight vector is represented by the following equation:

$$\mathbf{w}_m = \arg\left(\max_{\substack{\mathbf{w}_m \\ \|\mathbf{w}_m\|=1}}\left(\frac{\left|\mathbf{w}_m{}^{\mathrm{H}}\mathbf{c}_m\mathbf{c}_m{}^{H}\mathbf{w}_m\right|^2}{\mathbf{w}_m{}^{\mathrm{H}}\Phi\mathbf{w}_m}\right)\right)$$

where $\Phi = \sum_{k=0}^{K-1} A_k\mathbf{c}_k\mathbf{c}_k{}^{H} + B\cdot\mathbf{I}$.

8. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the weight vector is represented by the following equation:

$$\mathbf{w}_k = \frac{\Phi^{-1}\mathbf{c}_k}{\left\|\Phi^{-1}\mathbf{c}_k\right\|}.$$

where $\Phi = \sum_{k=0}^{K-1} A_k\mathbf{c}_k\mathbf{c}_k{}^{H} + B\cdot\mathbf{I}$.

9. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the parameter set comprises a normalized channel estimate and a cochannel gain matrix.

10. The method of generating weighted transmit signals with nulling as defined in Claim 9, wherein the parameter set further comprises an adjustment parameter for each receiver.

11. The method of generating weighted transmit signals with nulling as defined in Claim 9, wherein the initialization act (a) comprises initializing the normalized channel estimate according to the following equation:

$$\hat{\mathbf{c}}_m = \frac{\mathbf{a}}{\|\mathbf{a}\|}$$; where **a** is an arbitrary vector.

12. The method of generating weighted transmit signals with nulling as defined in Claim 10, wherein the initialization act (a) comprises initializing the adjustment parameter according to a quality of service requirement.

13. The method of generating weighted transmit signals with nulling as defined in Claim 10, wherein the updating the parameter set act (c) comprises updating the adjustment parameter according to a power control requirement.

14. The method of generating weighted transmit signals with nulling as defined in Claim 10, wherein the updating the parameter set act (c) comprises updating the adjustment parameter according to the following equation:

$$A_k = C_k\left(\frac{1}{P_k^{(T)}}\right) + D_k.$$

15. The method of generating weighted transmit signals with nulling as defined in Claim 14 wherein $P_k^{(T)}$ is a transmission power for the k^{th} receiver.

16. The method of generating weighted transmit signals with nulling as defined in Claim 15 wherein $P_k^{(T)}$ is determined through closed loop power control, wherein the receiver transmits power control information to the transmitter.

17. The method of generating weighted transmit signals with nulling as defined in Claim 14 wherein C_k and D_k are algorithm parameters that are selected to improve performance.

18. The method of generating weighted transmit signals with nulling as defined in Claim 9, wherein the updating the parameter set act (c) comprises updating the cochannel gain matrix according to the following equation:

$$\hat{\mathbf{\Phi}} = \sum_{k=0}^{K-1} A_k \hat{\mathbf{c}}_k \hat{\mathbf{c}}_k^H + B \cdot \mathbf{I}.$$

19. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the initialization act (a) comprises initializing the weight vector according to an arbitrary channel estimate vector with a norm of 1.

20. The method of generating weighted transmit signals with nulling as defined in Claim 1, wherein the updating the weight vector act (b) comprises updating the weight vector according to the following equation:

$$\mathbf{w}_m \Leftarrow \frac{f(\mathbf{w}_m, \mathbf{c}, \hat{\mathbf{\Phi}})}{\left\| f(\mathbf{w}_m, \mathbf{c}, \hat{\mathbf{\Phi}}) \right\|}.$$

21. The method of generating weighted transmit signals with nulling as defined in Claim 20 wherein the update adjusts $\mathbf{w}$ towards maximizing an inverse cost which is a function of $\mathbf{w}$, $\mathbf{c}$, $\hat{\mathbf{\Phi}}$.

22. The method of generating weighted transmit signals with nulling as defined in Claim 21 wherein the maximized inverse cost is given by

$$\frac{\left| \mathbf{w}_m^H(i) \mathbf{c}_m(i) \right|^2}{\mathbf{w}_m^H(i) \hat{\mathbf{\Phi}} \mathbf{w}_m^H(i)}.$$

23. The method of generating weighted transmit signals with nulling as defined in Claim 21 where the update is based upon feedback from the receiver.

24. A method of generating vector weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a plurality of receivers, and wherein the transmitter includes a plurality of antennae, the method comprising:

a) initializing a weight vector for each receiver;

b) initializing a set of adaptation parameters;

c) generating a transmit probing signal based on the weight vector and parameter set for each receiver within a subset of tracked receivers;

d) generating feedback based on the transmit probing signal generated in act (c) for each receiver within the subset of tracked receivers;

e) updating the weight vector by the transmitter based on the feedback generated in act (d) for each receiver; and

f) updating the parameter set by the transmitter based on the weight vector updated in act (e).

25. The method of generating weighted transmit signals with nulling as defined in Claim 24, wherein the updating the weight vector act (e) comprises the following sub-acts:

i) updating the weight vector periodically; and

ii) updating the weight vector upon receiving binary feedback.

26. The method of generating weighted transmit signals with nulling as defined in Claim 24, wherein the updating the generating the transmit probing signal sub-act (c) comprises the following sub-acts:

a) generating a test perturbation vector; and

b) computing an even weight, an odd weight and a data channel weight based on the test perturbation vector generated in sub-act a).

27. The method of generating weighted transmit signals with nulling as defined in Claim 26, wherein the generating sub-act a) comprises storing a current value of the test perturbation vector and generating a new current value of the test perturbation vector, v, according to the following equation:

$$\mathbf{v} \Leftarrow \text{test perturbation vector}, \mathrm{E}(\mathbf{v}) = 0, \mathrm{E}(\mathbf{v}\mathbf{v}^{\mathrm{H}}) = 2\mathbf{I};.$$

28. The method of generating weighted transmit signals with nulling as defined in Claim 27, wherein the updating the weight vector sub-act (e) of claim 24 comprises computing an even weight, an odd weight and a data channel weight based on the stored test perturbation vector

29. The method of generating weighted transmit signals with nulling as defined in Claim 26, wherein the test perturbation vector is a Gaussian test perturbation vector.

30. The method of generating weighted transmit signals with nulling as defined in Claim 26, wherein the computing sub-act b) comprises computing an even weight, an odd weight and a data channel weight according to the following equations:

$$\mathbf{w}_{even} \Leftarrow (\mathbf{w}_{base} + \beta \cdot \mathbf{v}) \cdot \sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} + \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} + \beta \cdot \mathbf{v})}};$$

$$\mathbf{w}_{odd} \Leftarrow (\mathbf{w}_{base} - \beta \cdot \mathbf{v}) \cdot \sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} - \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} - \beta \cdot \mathbf{v})}};$$

$$\mathbf{w} \Leftarrow \frac{\mathbf{w}_{even} + \mathbf{w}_{odd}}{2}.$$

31. The method of generating weighted transmit signals with nulling as defined in Claim 30, wherein a weight vector interference normalization is approximated according to the following equations:

Even equation: $$\sqrt{\frac{\mathbf{w}_{base}{}^{H}\hat{\Phi}\mathbf{w}_{base}}{(\mathbf{w}_{base}+\beta\cdot\mathbf{v})^{H}\hat{\Phi}(\mathbf{w}_{base}+\beta\cdot\mathbf{v})}} \cong 1-2\beta\frac{\mathrm{Re}(\mathbf{v}^{H}\hat{\Phi}\mathbf{w}_{base})}{\mathbf{w}_{base}{}^{H}\hat{\Phi}\mathbf{w}_{base}};$$

Odd equation: $$\sqrt{\frac{\mathbf{w}_{base}{}^{H}\hat{\Phi}\mathbf{w}_{base}}{(\mathbf{w}_{base}+\beta\cdot\mathbf{v})^{H}\hat{\Phi}(\mathbf{w}_{base}+\beta\cdot\mathbf{v})}} \cong 1+2\beta\frac{\mathrm{Re}(\mathbf{v}^{H}\hat{\Phi}\mathbf{w}_{base})}{\mathbf{w}_{base}{}^{H}\hat{\Phi}\mathbf{w}_{base}}.$$

32. The method of generating weighted transmit signals with nulling as defined in Claim 26, wherein the even and odd weight vectors are transmitted with multiplexing, where the even weight vector is applied with an even multiplex and the odd weight vector applied with an odd multiplex.

33. The method of generating weighted transmit signals with nulling as defined in Claim 32, wherein the even and odd weight vectors are transmitted with time multiplexing, where the even weight vector is applied in even time slots and the odd weight vector is applied in odd time slots.

34. The method of generating weighted transmit signals with nulling as defined in Claim 25, wherein the updating the weight vector upon receiving binary feedback sub-act (ii) comprises the following sub-acts:

a) receiving a feedback bit;

b) proceeding to a sub-act c) if the feedback bit indicates an even channel, else proceeding to a sub-act d);

c) updating a base vector based on an even weight, and proceeding to sub-act e);

d) updating the base vector based on an odd weight; and

e) computing new values for the even weight, the odd weight and a data channel weight based on the base vector.

35. The method of generating weighted transmit signals with nulling as defined in Claim 34, wherein the updating a base vector based on an even weight sub-act c) comprises updating according to the following equation:

$$\mathbf{w}_{base} \Leftarrow \frac{\mathbf{w}_{even}}{\left\|\mathbf{w}_{even}\right\|}.$$

36. The method of generating weighted transmit signals with nulling as defined in Claim 34, wherein the updating a base vector based on an odd weight sub-act d) comprises updating according to the following equation:

$$\mathbf{w}_{base} \Leftarrow \frac{\mathbf{w}_{odd}}{\left\|\mathbf{w}_{odd}\right\|}.$$

37. The method of generating weighted transmit signals with nulling as defined in Claim 34, wherein the computing new values sub-act e) comprises computing an even weight, an odd weight and a data channel weight according to the following equations:

$$\mathbf{w}_{even} \Leftarrow \left(\mathbf{w}_{base} + \beta \cdot \mathbf{v}\right) \cdot \sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} + \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} + \beta \cdot \mathbf{v})}};$$

$$\mathbf{w}_{odd} \Leftarrow \left(\mathbf{w}_{base} - \beta \cdot \mathbf{v}\right) \cdot \sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} - \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} - \beta \cdot \mathbf{v})}};$$

$$\mathbf{w} \Leftarrow \frac{\mathbf{w}_{even} + \mathbf{w}_{odd}}{2}.$$

38. The method of generating weighted transmit signals with nulling as defined in Claim 35, wherein a weight vector interference normalization is approximated according to the following equations:

Even equation: $$\sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} + \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} + \beta \cdot \mathbf{v})}} \cong 1 - 2\beta \frac{\mathrm{Re}(\mathbf{v}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base})}{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}};$$

Odd equation: $$\sqrt{\frac{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}{(\mathbf{w}_{base} - \beta \cdot \mathbf{v})^{\mathrm{H}} \hat{\mathbf{\Phi}} (\mathbf{w}_{base} - \beta \cdot \mathbf{v})}} \cong 1 + 2\beta \frac{\mathrm{Re}(\mathbf{v}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base})}{\mathbf{w}_{base}{}^{\mathrm{H}} \hat{\mathbf{\Phi}} \mathbf{w}_{base}}.$$

39. The method of generating weighted transmit signals with nulling as defined in Claim 24 wherein the updating the parameter set act (f) comprises a normalized channel estimate parameter according to the following equation:

$$\hat{\mathbf{c}}_m = \frac{\hat{\Phi}\mathbf{w}_m}{\left\|\hat{\Phi}\mathbf{w}_m\right\|}.$$

40. The method of generating weighted transmit signals with nulling as defined in Claim 24, wherein the updating the parameter act (e) comprises updating a cochannel gain matrix according to the following equation:

$$\hat{\Phi} \Leftarrow \sum_{k=0}^{K-1} A_k \hat{\mathbf{c}}_k \hat{\mathbf{c}}_k^H + B \cdot \mathbf{I}.$$

41. A method of generating weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a receiver, and wherein the transmitter includes a plurality of antennae, the method comprising:

a) initializing a plurality of baseband transmit weight vectors and a plurality of channel estimate vectors for multiple tracked transmissions;

b) updating the plurality of baseband transmit weight vectors based on a metric of a cross interference and a plurality of channel estimates;

c) updating the plurality of channel estimates based on the plurality of baseband transmit weight vectors; and

d) returning to act (b).

42. A communication system, capable of generating weighted transmit signals with nulling, comprising:

a) a transmitter, capable of initializing a parameter set and a weight vector associated with the transmitter and updating the weight vector based on an inverse cost function, and updating the weight vector means, and generating even and odd probing signals, for updating the parameter set; and

b) a receiver, capable of providing feedback regarding even and odd channel strength.

43. A transmitter, capable of generating weighted transmit signals with nulling, comprising:

a) an initializer, adapted to initialize a parameter set and a weight vector associated with the transmitter;

b) a first update device, responsive to the initializer, adapted to update the weight vector based on an inverse cost function; and

c) a second update device, responsive to the updating the weight vector means, adapted to update the parameter set.

44. An apparatus for generating weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a receiver, and wherein the transmitter includes a plurality of antennae, comprising:

a) means for initializing a parameter set and a weight vector associated with the transmitter;

b) means, responsive to the initialization means, for updating the weight vector based on an inverse cost function; and

c) means, responsive to the updating the weight vector means, for updating the parameter set.

45. An apparatus for generating weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a receiver, and wherein the transmitter includes a plurality of antennae, comprising:

a) means for initializing a plurality of baseband transmit weight vectors and a plurality of channel estimate vectors for multiple tracked transmissions;

b) means, responsive to the initialization means, for updating the plurality of baseband transmit weight vectors based on a metric of a cross interference and a plurality of channel estimates; and

c) means, responsive to the updating the weight vector means, for updating the plurality of channel estimates based on the plurality of baseband transmit weight vectors.

46. A computer program executable on a general purpose computing device, wherein the program is capable of generating weighted transmit signals with nulling in a communication system, wherein the communication system includes a transmitter and a receiver, and wherein the transmitter includes a plurality of antennae, comprising:

a) a first set of instructions for initializing a parameter set and a weight vector;

b) a second set of instructions for updating the weight vector based on an inverse cost function;

c) a third set of instructions for updating the parameter set; and

d) a fourth set of instructions for returning to the act (b).